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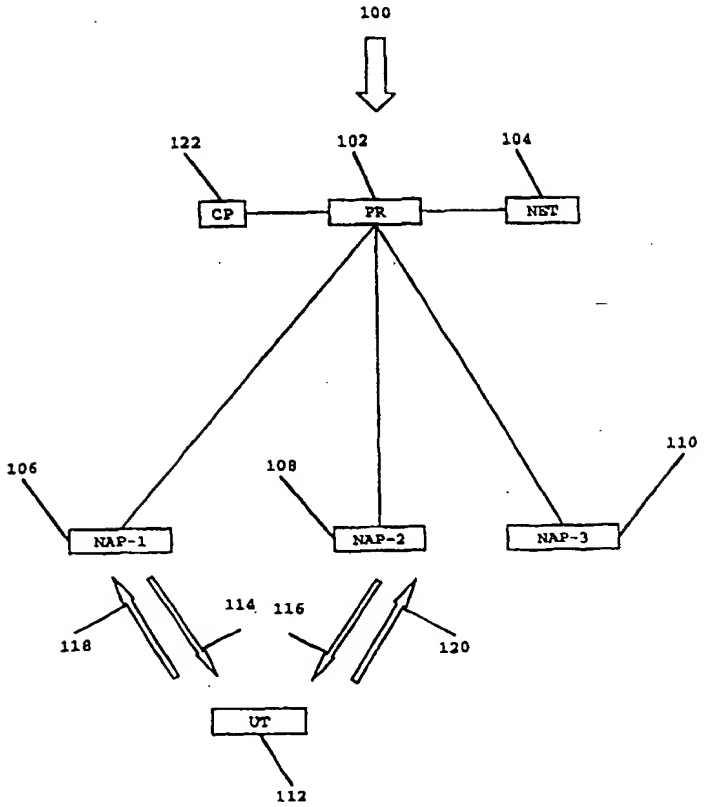
(54) Title: DISTRIBUTED INFRASTRUCTURE FOR WIRELESS DATA COMMUNICATIONS

(57) Abstract

A mobile user terminal (402) accesses a packet data network (450) through one or more of several network access points (404–412). One or more control points (432–440) determines which network access point or points the user terminal is to access. Control may be retained in the current control point, or transferred to another control point, whenever it is convenient. There are preferably several routers, each having an associated home agent (418–420) which determines which foreign agents need to be accessed on behalf of each user terminal. There are several foreign agents (422–430), which forward packets received from a user terminal's home agent to the control point currently controlling communications with the user terminal.



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DISTRIBUTED INFRASTRUCTURE FOR WIRELESS DATA COMMUNICATIONS

BACKGROUND OF THE INVENTION

Technical Field

This invention pertains to wireless communications systems and, in particular, to wireless packet data networks.

Background Art

Figure 1

Figure 1 shows a conventional single-router wireless packet data network 100. A packet router 102 receives data packets from the remainder of a network 104 and routes them to one or more network access points 106-110. The network access points 106-110 transmit the packets forward to a user terminal 112 over forward wireless links 114-116. The user terminal 112 transmits packets back to the network access points 106-110 over reverse wireless links 118-120. The user terminal 112 may be a cellular telephone carried by a person, a portable computer, a mobile telephone in an automobile, or any other mobile device which must continue to provide connectivity even while it moves.

A control point 122 is connected to the packet router 102. It manages the wireless links 114-120. Management includes many functions. For example, as the user terminal 112 moves around the path loss between it and the network access points 106-110 changes. In the situation shown in Figure 1, the control point 122 must cause the user terminal 112 to transmit with the minimum amount of power required to be received by at least one of network access points 106-108. Mobile station transmit power is minimized since it causes interference to transmissions from other mobile

stations. When the user terminal moves from the area served by network access point 106 to the area served by network access point 108, there will be a handoff of the user terminal 112 from network access point 106 to network access point 108. The control point 122 must manage the handoff. Other management functions are known to those with skill in the art.

Figure 2

Figure 2 shows a conventional multiple-router wireless packet data network 200 supporting a mobility protocol such as Mobile IP as described in the Internet Engineering Task Force RFC 2002. A second packet router 202 is connected to the first packet router 102, to the rest of the network 104, or (as shown) to both. Second packet router 202 is connected to network access points 204-206. In Figure 2, the user terminal 112 is moving from the area served by network access point 110 (where it is served by forward link 208) to the area served by network access point 204 (where it is served by forward link 210). Control point 122 manages the wireless links during this handoff (including the management of reverse links 212-214) in much the same way as during the handoff shown in Figure 1. If desired, control can be passed from first control point 122 to second control point 222. These control points are connected to first and second packet routers 102 and 202, respectively.

Figure 2 also shows a home agent 224 and a foreign agent 226. Home agent 224 is connected to first packet router 102, and foreign agent 226 is connected to second packet router 202.

User terminal 112 has a network address for which packet router 102 advertises reachability. A packet intended for user terminal 112 is therefore sent to first packet router 102. When user terminal 112 is in the coverage area of network access points associated with packet router 102 (106-110), packet router 102 will forward the packet to control point 122 which will send the packet for transmission to the network access points that currently provide a forward wireless link to the user terminal 112.

User terminal 112 may leave the area served by first packet router 102 and may enter the area served by second packet router 202. The net 104 will send packets destined to user terminal 112 to packet router 102 which will then forward them to home agent 224 which maintains track of user terminal 112's current location in the form of a "care-of" address. The home agent will then encapsulate these packets in packets destined to the care-of address of the user terminal (e.g., foreign agent 226) and send these packets through packet routers 102 and 202. Upon receiving these packets, foreign agent 226 will de-capsulate the packets and forward the packets destined for transmission to user terminal 112 to control point 222. Control point 222 will then forward the packets for transmission to the network access points that currently provide a forward wireless link to the user terminal 112.

In this method, control of the network access points for a data connection has moved from control point 122 to control point 222. In another conventional method, control does not move between the two control points, in which case packet router 102 continues to forward packets for transmission to user terminal 112 to control point 122 which then sends the packets directly to whatever network access points provide a forward wireless link to user terminal 112, regardless of the system in which these network access points are located. E.g., control point 122 may forward packets for transmission to network access points 106-110 as well as 204-206.

This architecture suffers from several fundamental problems: the control points for each part of the network are single points of failure which must be made highly reliable, increasing their cost. Furthermore, since they are unique for each network, the architecture does not scale well as the number of network access points increase, increasing with it the population of mobile terminals that can be served and consequently, the load presented to the control points. Last, emerging high speed wireless protocols require low-latency control by the control point which is not possible due to the transmission and queuing delays between the control points and the network access points.

Disclosure of Invention

Applicants provide a solution to the shortcomings of the previously described architecture by distributing the functionality of the control points and allowing the co-location of a control point with every network access point. The architecture proposed by the applicants is further optimized by co-locating foreign agents with the network access points and control points.

Brief Description of Drawings

Figure 1 shows a conventional single-router wireless packet data network.

Figure 2 shows a conventional multiple-router wireless packet data network.

Figure 3 shows a single-router wireless packet data network, according to the present invention.

Figure 4 shows a multiple-router wireless packet data network, according to the present invention.

Modes for Carrying Out the Invention

Figure 3

Figure 3 shows a single-router wireless packet data network 300, according to the present invention.

A user terminal 302 is configured to transmit and receive wireless data packets. There is plurality of network access points 304-308, each being configured to transmit wireless data packets to, and to receive them from, the user terminal 302. A router 310 is capable of transmitting data packets to, and receiving them from, the network access points 304-308. Figure 3 shows the situation in which a user terminal is leaving the area served by first

network access point 304 and is entering the area served by second network access point 306.

There is a plurality of control points 312-316. As in the prior art, each control point is configured to manage a wireless link 318-324 between the user terminal 302 and the selected network access point 304-308. However, there are plural control points 312-316 instead of a single control point 122. In this invention, a user terminal is served by the control point that is co-located with the first network access point with which the user terminal has established communications for a particular data exchange. In the example of Figure 3, user terminal 302 is currently connected to both network access points 304 and 306. If the first network access point to serve the user terminal was network access point 304, the control point will be control point 312. Otherwise, the control point will be control point 314. Using this convention multiple user terminals accessing the network will be controlled by a plurality of control points thus sharing the load between the control points. Furthermore, a failure of a control point would only affect the user terminals served by it, rather than the entire population of user terminals.

Each control point 312-316 is configured to select a network access point 304-308 to communicate with the user terminal 302. In Figure 3, first control point 312 has selected first network access point 304 as the network access point to communicate with the user terminal 302. However, as user terminal 302 leaves the area served by first network access point 304 and enters the area served by second network access point 306, first control point 312 selects both network access points 304, 306 to communicate with user terminal 302. First control point 312 then selects only second network access point 306 to communicate with user terminal 302, thus effecting a soft handoff. First control point 312 may retain control even after the process has ended, or it may transfer control to second control point 314. Third control point 316 was not used during the process just described, but remains available in case user terminal 302 moves into the area served by third network access point 308. The operator may establish any convenient

method for determining when to retain control in the current control point and when to transfer control to another control point.

Soft handoff is not the only possible event which triggers a decision on whether to retain control in the current control point or to transfer control to another control point. Load sharing, failure of a control point, and similar considerations may be used by the operator to determine when to trigger a decision.

Using a mobility protocol such as Internet Engineering Task Force RFC 2002, packets destined to user terminal 302 are routed from router 310 to the control point that currently control communications with user terminal 302.

The actual network access point used to communicate with the user terminal may be different from the control point's associated network access point, or may be the same.

If desired, each control point may be configured to select a plurality of network access points to concurrently communicate with the user terminal. In this case, all of the selected network access points may be different from the control point's associated network access point, or one of the selected network access points may be the same as to control point's associated network access point.

Each control point may be configured, if desired, to cache data link protocol information for the user terminal during periods when the user terminal is not assigned a traffic channel. If this is done, the caching control point may be associated with the network access point first used by the user terminal, with the network access point last used by the user terminal, or any other point.

Figure 4

Figure 4 shows a multiple-router wireless packet data network 400, according to the present invention.

A user terminal 402 is configured to transmit and receive wireless data packets. There is a plurality of network access points 404-412, each

configured to transmit wireless data packets to, and to receive them from, the user terminal 402. There are one or more routers 414-416 capable of transmitting data packets to, and receiving them from, the network access points 404-412. Each network access point 404-412 is connected to only one router 414-416. There are one or more home agents 418-420. Each home agent 418-420 is associated with a router 414-416. The home agents encapsulate packets destined to user terminals registered with them in packets destined to the current care-of address of the user terminal. This address is the address of the foreign agent co-located with the control point that is controlling communications with the user terminal. The foreign agent may be connected to the same router as the home agent or to a different router. The use of home agents and foreign agents is well known to those skilled in the art and is described in such mobility protocols as Internet Engineering Task Force RFC 2002.

There is a plurality of foreign agents 422-430. Each foreign agent 422-430 is also associated with a network access point 404-412 and a control point 432-440. Each foreign agent is configured to receive packets for user terminals currently being served by the control point co-located with it. The foreign agent receives packets destined to it. If these packets contain packets destined to such user terminals, it de-capsulates these packets and forwards them to the control point.

There is a plurality of control points 432-440. As in Figure 3, each control point 432-440 is associated with a network access point 404-412. Each control point 432-440 is configured to select one or more network access points 404-412 to communicate with the user terminal 402. Each control point 432-440 is further configured to manage a wireless link 442-448 between the user terminal 402 and the selected network access point or points 408-410. The user terminal 402 thus stays in communication with the rest of the network 450 even when moving.

The selected network access point may be different from, or the same as, the control point's associated network access point.

Each control point may be configured to select a plurality of network access points to concurrently communicate with the user terminal. If so, all

of the selected network access points may be different from the control point's associated network access point, or one of them may be the same.

Following a handoff, control may either remain in the original control point or may be transferred to the control point associated with the new network access point. As in the apparatus of Figure 3, the operator may establish any convenient method for determining when to retain control in the current control point and when to transfer control to another control point. Also as in the apparatus of Figure 3, soft handoff is not the only possible event which triggers a decision on whether to retain control in the current control point or to transfer control to another control point. Load sharing, failure of a control point, and similar considerations may be used by the operator to determine when to trigger a decision.

In any event, each control point may be further configured to cache data link protocol information for the user terminal during periods when the user terminal is not assigned a traffic channel. This may be done in the control point associated with the network access point first used by the user terminal, last used by the user terminal, or any other control point.

Industrial Applicability

The present invention is capable of exploitation in industry, and can be made and used, whenever a distributed packet data network providing mobility is desired.

Several examples and modes for practicing the present description are described herein. However, the true spirit and scope of the invention are not limited thereto, but are limited only by the appended claims and their equivalents.

CLAIMS

1) An article of manufacture, comprising in combination:

a) a user terminal configured to transmit and receive wireless data packets;

b) a plurality of network access points, each being configured to transmit wireless data packets to, and to receive them from, the user terminal;

c) a router connected to transmit data packets to, and to receive them from, the network access points; and

d) a plurality of control points, each control point being:

1) associated with a network access point; and

2) configured to:

(A) select a network access point to communicate with the user terminal;

(B) manage a wireless link between the user terminal and the selected network access point; and

(C) retain control, or transfer control to another control point, according to a pre-established determination.

2) The article of Claim 1, wherein the selected network access point is different from the control point's associated network access point.

3) The article of Claim 1, wherein each control point is configured to select a plurality of network access points to concurrently communicate with the user terminal.

4) The article of Claim 3, wherein all of the selected network access points are different from the control point's associated network access point.

5) The article of Claim 1, wherein each control point is further configured to cache data link protocol information for the user terminal during periods when the user terminal is not assigned a wireless forward link, or is not assigned a wireless reverse link, or is assigned neither a wireless forward link nor a wireless reverse link.

6) The article of Claim 5, wherein the caching control point is associated with the network access point first used by the user terminal.

7) The article of Claim 5, wherein the control point is associated with the network access point last used by the user terminal.

8) An article of manufacture, comprising in combination:

a) a user terminal configured to transmit and receive wireless data packets;

b) a plurality of network access points, each configured to transmit wireless data packets to, and to receive them from, the user terminal;

c) one or more routers connected to transmit data packets to, and to receive them from, the network access points, each network access point being connected to only one router;

d) one or more home agents, each home agent being:

1) associated with a router; and

2) configured to select one or more of the below-recited foreign agents to forward packets to the user terminal

e) a plurality of foreign agents, each foreign agent:

1) also being associated with a network access point;

2) being configured to forward data packets from a user terminal's home agent to the control point that is currently controlling communications with the user terminal; and

3) supporting transfer of communications control for a particular user terminal between different control points;

f) a plurality of control points, each control point being:

1) associated with a network access point;

2) configured to:

(A) select one or more network access points to communicate with the user terminal;

(B) manage a wireless link between the user terminal and the selected network access point; and

(C) retain control, or transfer control to another control point, according to a pre-established determination.

9) The article of Claim 8, wherein the selected network access point is different from the control point's associated network access point.

10) The article of Claim 8, wherein each control point is configured to select a plurality of network access points to concurrently communicate with the user terminal.

11) The article of Claim 10, wherein all of the selected network access points are different from the control point's associated network access point.

12) The article of Claim 8, wherein each control point is further configured to cache data link protocol information for the user terminal during periods when the user terminal is not assigned a traffic channel.

13) The article of Claim 12, wherein the control points are configured to cache data link protocol information in the control point associated with the network access point first used by the user terminal.

14) The article of Claim 12, wherein the control points are configured to cache data link protocol information in the control point associated with the network access point last used by the user terminal.

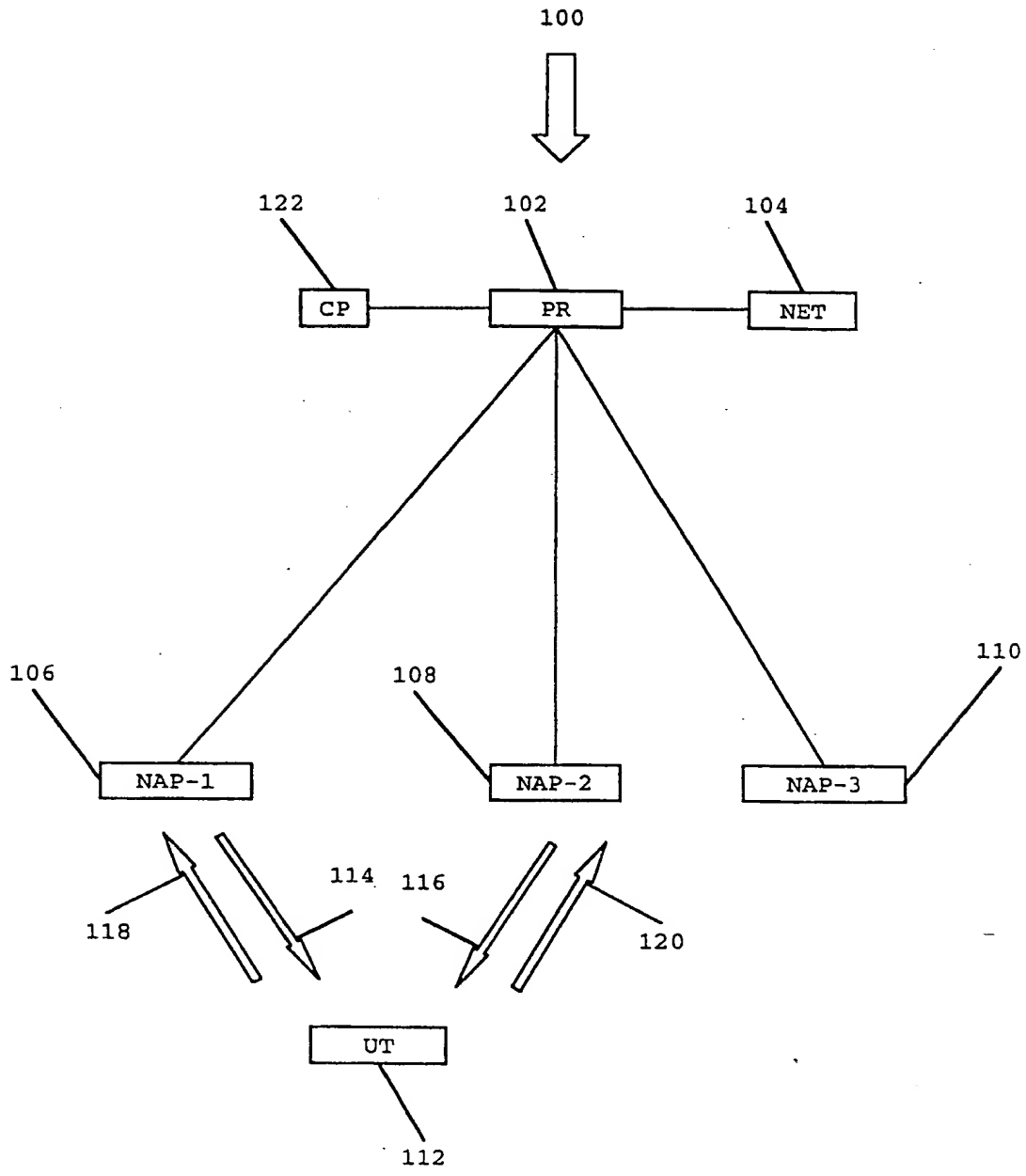

FIG. 1
PRIOR ART

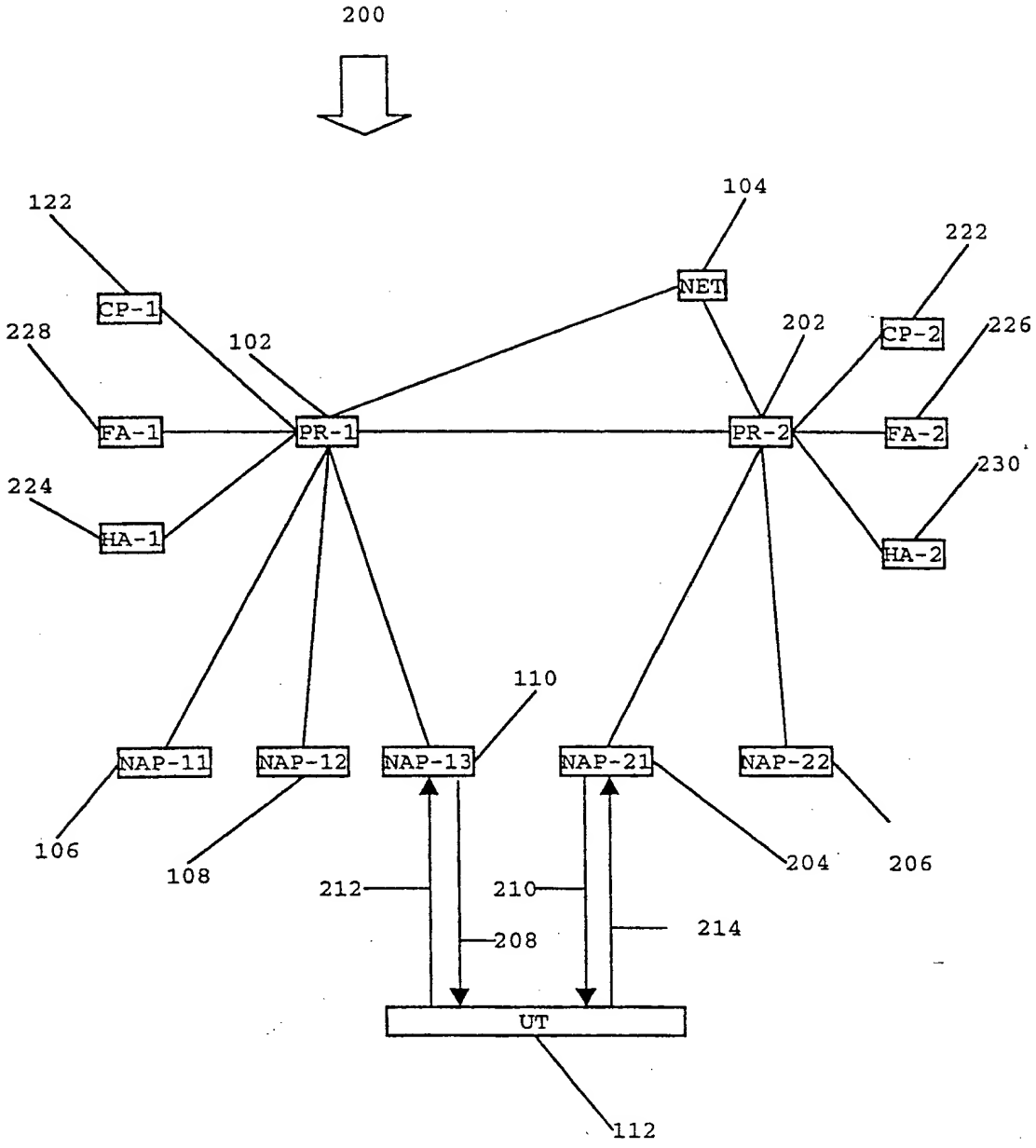

FIG. 2
PRIOR ART

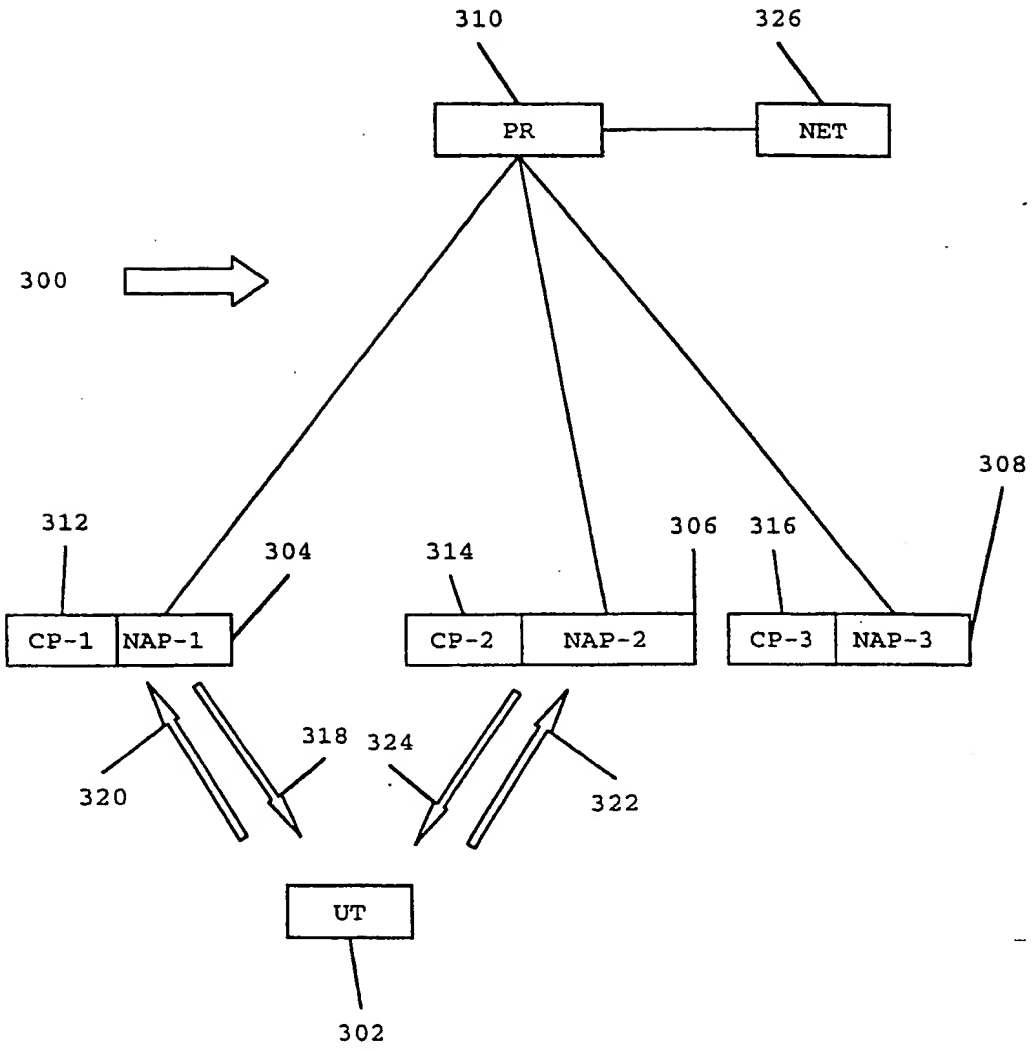
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FIG. 3

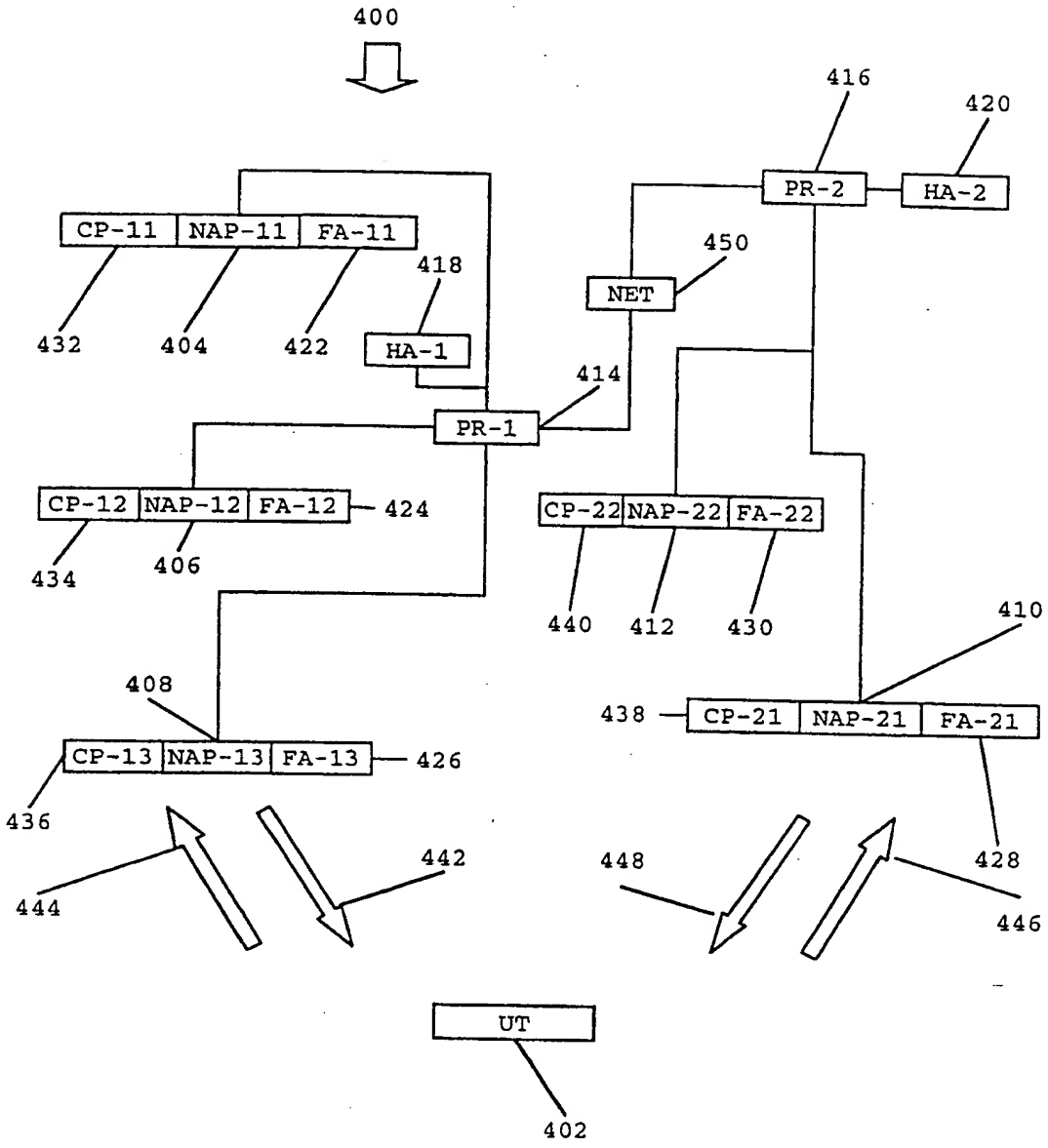
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FIG. 4